

# LM21215 2.95-V to 5.5-V, 12-A, Voltage-Mode Synchronous Buck Regulator

## 1 Features

- Integrated 7-mΩ high-side and 4.3-mΩ low-side FET switches
- Adjustable current limit
- Adjustable output voltage from 0.6 V to  $V_{IN}$  (100% duty cycle capable),  $\pm 1\%$  reference
- 2.95-V to 5.5-V input voltage range
- 500-kHz fixed switching frequency
- Start-up into prebiased loads
- Output voltage tracking capability
- Wide bandwidth voltage loop error amplifier
- Adjustable soft start with external capacitor
- Precision enable pin with hysteresis
- Integrated OVP, OTP, UVLO, and power good
- Thermally enhanced 20-pin HTSSOP exposed pad package
- Create a custom design using the LM21215 with the [WEBENCH® Power Designer](#)

## 2 Applications

- Broadband, networking, and [wireless communications](#)
- High-performance FPGAs, ASICs, and microprocessors
- Simple-to-design, high-efficiency point-of-load regulation from a 5-V or 3.3-V bus

## 3 Description

The LM21215 is a monolithic synchronous point-of-load buck regulator that is capable of delivering up to 15 A of continuous output current while producing an output voltage down to 0.6 V with outstanding

efficiency. The device is optimized to work over an input voltage range of 2.95 V to 5.5 V, making it suitable for a wide variety of low voltage systems. The voltage mode control loop provides high noise immunity, narrow duty cycle capability and can be compensated to be stable with any type of output capacitance, providing maximum flexibility and ease of use.

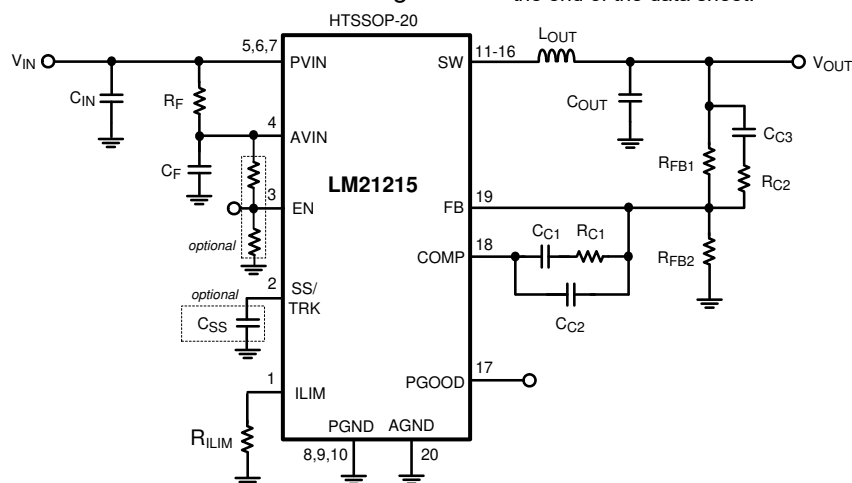
The LM21215 features internal overvoltage protection (OVP) and resistor-programmable overcurrent protection (OCP) for increased system reliability. A precision enable pin and integrated UVLO allow turn-on of the device to be tightly controlled and sequenced. Start-up inrush currents are limited by both an internally fixed and externally adjustable soft-start circuit. Fault detection and supply sequencing are possible with the integrated power good circuit.

The LM21215 is designed to work well in multi-rail power supply architectures. The output voltage of the device can be configured to track an external voltage rail using the SS/TRK pin. If the output is prebiased at start-up, it will not sink current, allowing the output to smoothly rise past the prebiased voltage. The regulator is offered in a 20-pin HTSSOP package with an exposed pad that can be soldered to the PCB, eliminating the need for bulky heat sinks.

### Device Information

| PART NUMBER | PACKAGE <sup>(1)</sup> | BODY SIZE (NOM)   |
|-------------|------------------------|-------------------|
| LM21215     | HTSSOP (20)            | 6.50 mm × 4.40 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.



**Simplified Application Circuit**



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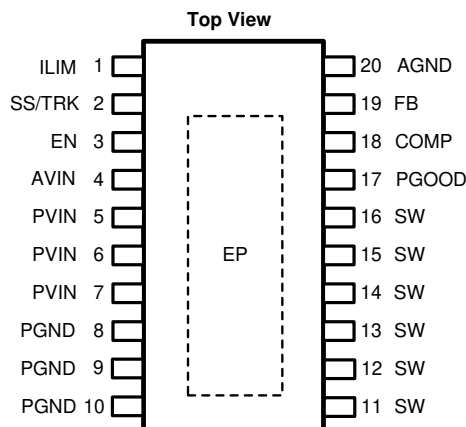
## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| <b>Changes from Revision F (June 2019) to Revision G (March 2022)</b>                                  | <b>Page</b> |
|--|-------------|
| • Updated the numbering format for tables, figures, and cross-references throughout the document. .... | <b>1</b>    |
| • Removed reference to adjustable frequency.....   | <b>10</b>   |
| • Removed reference to adjustable frequency.....   | <b>15</b>   |

| <b>Changes from Revision E (March 2013) to Revision F (June 2019)</b>        | <b>Page</b> |
|--|-------------|
| • Editorial changes only, no technical revisions; add links for WEBENCH..... | <b>1</b>    |

## 5 Pin Configuration and Functions



**Figure 5-1. 20-Pin HTSSOP Package PWP Package (Top View)**

**Table 5-1. Pin Functions**

| PIN    |             |   |
|--------|-------------|---|
| NO.    | NAME        | DESCRIPTION   |
| 1      | ILIM        | Resistor-programmable current limit pin. A resistor connected to this pin and ground sets the value of the rising current limit, $I_{CLR}$ . Shorting this pin to AGND programs the device to the maximum possible current limit.                 |
| 2      | SS/TRK      | Soft-start control pin. An internal 2- $\mu$ A current source charges an external capacitor connected between this pin and AGND to set the output voltage ramp rate during start-up. This pin can also be used to configure the tracking feature. |
| 3      | EN          | Active high enable input for the device. If not used, the EN pin can be left open, which goes high due to an internal current source.   |
| 4      | AVIN        | Analog input voltage supply that generates the internal bias. It is recommended to connect PVIN to AVIN through a low pass RC filter to minimize the influence of input rail ripple and noise on the analog control circuitry.                    |
| 5,6,7  | PVIN        | Input voltage to the power switches inside the device. These pins should be connected together at the device. A low-ESR input capacitance should be located as close as possible to these pins.   |
| 8,9,10 | PGND        | Power ground pins for the internal power switches   |
| 11-16  | SW          | Switch node pins. These pins should be tied together locally and connected to the filter inductor.  |
| 17     | PGOOD       | Open-drain power good indicator   |
| 18     | COMP        | Compensation pin is connected to the output of the voltage loop error amplifier   |
| 19     | FB          | Feedback pin is connected to the inverting input of the voltage loop error amplifier  |
| 20     | AGND        | Quiet analog ground for the internal reference and bias circuitry   |
| EP     | Exposed Pad | Exposed metal pad on the underside of the package with an electrical and thermal connection to PGND. TI recommends connecting this pad to the PC board ground plane in order to improve thermal dissipation.                                      |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

See

|  |                        |
|--|------------------------|
| PVIN <sup>(1)</sup> , AVIN to GND                      | –0.3 V to +6 V         |
| SW <sup>(2)</sup> , EN, FB, COMP, PGOOD, SS/TRK to GND | –0.3 V to PVIN + 0.3 V |
| Storage temperature                                    | –65°C to 150°C         |
| Lead temperature (soldering, 10 s)                     | 260°C                  |

- (1) The PVIN pin can tolerate transient voltages up to 6.5 V for a period of up to 6 ns. These transients can occur during the normal operation of the device.
- (2) The SW pin can tolerate transient voltages up to 9.0 V for a period of up to 6 ns, and –1 V for a duration of 4 ns. These transients can occur during the normal operation of the device.

### 6.2 ESD Ratings

|                    |                         |   | VALUE | UNIT |
|--------------------|-------------------------|---|-------|------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup> | ±2000 | V    |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Ratings

See <sup>(1)</sup>

|                              |                   |
|------------------------------|-------------------|
| PVIN, AVIN to GND            | +2.95 V to +5.5 V |
| Junction temperature         | –40°C to +125°C   |
| $\theta_{JA}$ <sup>(2)</sup> | 24°C/W            |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Recommended operating ratings indicate conditions for which the device is intended to be functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the *Electrical Characteristics*.
- (2) Thermal measurements were performed on a 2-inch × 2-inch, 4-layer, 2-oz. copper outer layer, 1-oz. copper inner layer board with twelve 8-mil. vias under the EP of the device and an additional sixteen 8-mil. vias under the unexposed package.

### 6.4 Electrical Characteristics

Unless otherwise stated, the following conditions apply:  $V_{PVIN, AVIN} = 5$  V. Limits in standard type are for  $T_J = 25^\circ\text{C}$  only, limits in **boldface type** apply over the junction temperature ( $T_J$ ) range of  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$ . Minimum and maximum limits are specified through test, design, or statistical correlation. Typical values represent the most likely parametric norm at  $T_J = 25^\circ\text{C}$ , and are provided for reference purposes only.

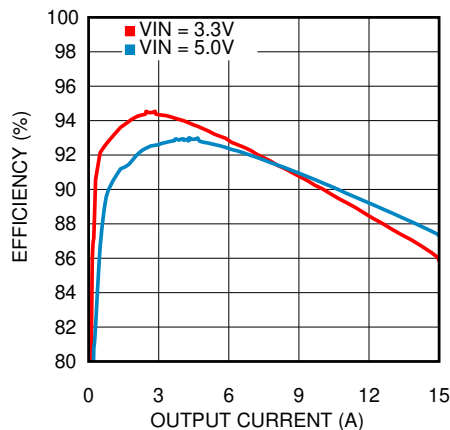
| PARAMETER                       |                                 | TEST CONDITIONS                 | MIN  | TYP  | MAX  | UNIT                 |
|---------------------------------|---------------------------------|---------------------------------|------|------|------|----------------------|
| <b>SYSTEM</b>                   |                                 |                                 |      |      |      |                      |
| V <sub>FB</sub>                 | Feedback pin voltage            | V <sub>IN</sub> = 2.95V to 5.5V | -1%  | 0.6  | 1%   | V                    |
| $\Delta V_{OUT}/\Delta I_{OUT}$ | Load Regulation                 |                                 |      | 0.02 |      | %V <sub>OUT</sub> /A |
| $\Delta V_{OUT}/\Delta V_{IN}$  | Line Regulation                 |                                 |      | 0.1  |      | %V <sub>OUT</sub> /V |
| R <sub>DS(on) HS</sub>          | High Side Switch On Resistance  | I <sub>SW</sub> = 12A           |      | 7    | 9.0  | mΩ                   |
| R <sub>DS(on) LS</sub>          | Low Side Switch On Resistance   | I <sub>SW</sub> = 12A           |      | 4.3  | 6.0  | mΩ                   |
| I <sub>CLR</sub>                | HS Rising Switch Current Limit  | R <sub>ILIM</sub> = 16.5 kΩ     | 16.5 | 20   | 23.5 | A                    |
|                                 |                                 | R <sub>ILIM</sub> = 41.3 kΩ     | 8.5  | 10   | 11.5 |                      |
|                                 |                                 | R <sub>ILIM</sub> = 130 kΩ      |      | 3.8  |      |                      |
| I <sub>CLF</sub>                | LS Falling Switch Current Limit | R <sub>ILIM</sub> = 16.5 kΩ     |      | 14.5 |      | A                    |
|                                 |                                 | R <sub>ILIM</sub> = 41.3 kΩ     |      | 7.5  |      |                      |
|                                 |                                 | R <sub>ILIM</sub> = 130 kΩ      |      | 3    |      |                      |
| V <sub>ZX</sub>                 | Zero Cross Voltage              |                                 | -8   | 3    | 12   | mV                   |
| I <sub>Q</sub>                  | Operating Quiescent Current     |                                 |      | 1.5  | 3    | mA                   |
| I <sub>SD</sub>                 | Shutdown Quiescent Current      | V <sub>EN</sub> = 0V            |      | 50   | 70   | μA                   |

Unless otherwise stated, the following conditions apply:  $V_{PVIN, AVIN} = 5\text{ V}$ . Limits in standard type are for  $T_J = 25^\circ\text{C}$  only, limits in **boldface type** apply over the junction temperature ( $T_J$ ) range of  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$ . Minimum and maximum limits are specified through test, design, or statistical correlation. Typical values represent the most likely parametric norm at  $T_J = 25^\circ\text{C}$ , and are provided for reference purposes only.

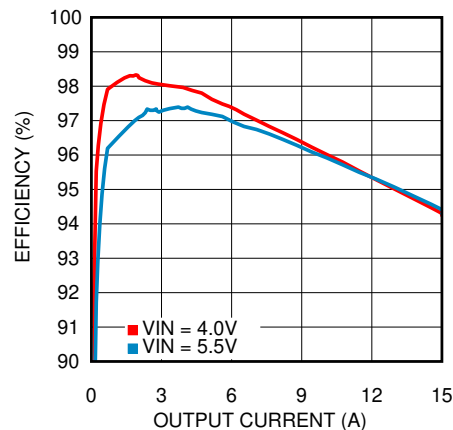
| PARAMETER               |  | TEST CONDITIONS                             | MIN         | TYP   | MAX         | UNIT             |
|-------------------------|--|---|-------------|-------|-------------|------------------|
| <b>SYSTEM</b>           |  |   |             |       |             |                  |
| $V_{UVLO}$              | AVIN Under Voltage Lockout                                       | AVIN Rising                                 | <b>2.45</b> | 2.7   | <b>2.95</b> | V                |
| $V_{UVLOHYS}$           | AVIN Under Voltage Lockout Hysteresis                            |   | <b>140</b>  | 200   | <b>280</b>  | mV               |
| $V_{TRACKOS}$           | SS/TRACK PIN accuracy ( $V_{SS} - V_{FB}$ )                      | $0 < V_{TRACK} < 0.55\text{V}$              | <b>-10</b>  | 6     | <b>20</b>   | mV               |
| $I_{SS}$                | Soft-Start Pin Source Current                                    |   | <b>1.3</b>  | 1.9   | <b>2.5</b>  | $\mu\text{A}$    |
| $t_{INTSS}$             | Internal Soft-Start Ramp to Vref                                 | $C_{SS} = 0$                                | <b>350</b>  | 500   | <b>675</b>  | $\mu\text{s}$    |
| $t_{RESETSS}$           | Device reset to soft-start ramp                                  |   | <b>50</b>   | 110   | <b>200</b>  | $\mu\text{s}$    |
| <b>OSCILLATOR</b>       |  |   |             |       |             |                  |
| $f_{OSC}$               | Switching Frequency  |   | <b>475</b>  | 500   | <b>525</b>  | kHz              |
| $t_{HSBLANK}$           | HS OCP blanking time   | Rising edge of SW to $I_{CLR}$ comparison   |             | 55    |             | ns               |
| $t_{LSBLANK}$           | LS OCP blanking time   | Falling edge of SW to $I_{CLF}$ comparison  |             | 400   |             | ns               |
| $t_{ZXBLANK}$           | Zero Cross blanking time   | Falling edge of SW to $V_{ZX}$ comparison   |             | 120   |             | ns               |
| $t_{MINON}$             | Minimum HS on-time   |   |             | 140   |             | ns               |
| $\Delta V_{RAMP}$       | PWM Ramp p-p Voltage   |   |             | 0.8   |             | V                |
| <b>ERROR AMPLIFIER</b>  |  |   |             |       |             |                  |
| $V_{OL}$                | Error Amplifier Open Loop Voltage Gain                           | $I_{COMP} = -65\mu\text{A}$ to $1\text{mA}$ |             | 95    |             | dBV/V            |
| GBW                     | Error Amplifier Gain-Bandwidth Product                           |   |             | 11    |             | MHz              |
| $I_{FB}$                | Feedback Pin Bias Current  | $V_{FB} = 0.6\text{V}$                      |             | 1     |             | nA               |
| $I_{COMPSRC}$           | COMP Output Source Current                                       |   |             | 1     |             | mA               |
| $I_{COMPSINK}$          | COMP Output Sink Current   |   |             | 65    |             | $\mu\text{A}$    |
| <b>POWERGOOD</b>        |  |   |             |       |             |                  |
| $V_{OVP}$               | Overvoltage Protection Rising Threshold                          | $V_{FB}$ Rising                             | <b>105</b>  | 112.5 | <b>120</b>  | $\%V_{FB}$       |
| $V_{OVPHYS}$            | Overvoltage Protection Hysteresis                                | $V_{FB}$ Falling                            |             | 2     |             | $\%V_{FB}$       |
| $V_{UVP}$               | Undervoltage Protection Rising Threshold                         | $V_{FB}$ Rising                             | <b>82</b>   | 90    | <b>97</b>   | $\%V_{FB}$       |
| $V_{UVPHYS}$            | Undervoltage Protection Hysteresis                               | $V_{FB}$ Falling                            |             | 2.5   |             | $\%V_{FB}$       |
| $t_{PGDGL}$             | PGOOD Deglitch Low (OVP/UVP Condition Duration to PGOOD Falling) |   |             | 15    |             | $\mu\text{s}$    |
| $t_{PGDGH}$             | PGOOD Deglitch High (minimum low pulse)                          |   |             | 12    |             | $\mu\text{s}$    |
| $R_{PD}$                | PGOOD Pulldown Resistance  |   | <b>10</b>   | 20    | <b>40</b>   | $\Omega$         |
| $I_{PGOODLEAK}$         | PGOOD Leakage Current  | $V_{PGOOD} = 5\text{V}$                     |             | 1     |             | nA               |
| <b>LOGIC</b>            |  |   |             |       |             |                  |
| $V_{IHENR}$             | EN Pin Rising Threshold  | $V_{EN}$ Rising                             | <b>1.20</b> | 1.35  | <b>1.45</b> | V                |
| $V_{ENHYS}$             | EN Pin Hysteresis  |   | <b>50</b>   | 110   | <b>180</b>  | mV               |
| $I_{EN}$                | EN Pin Pullup Current  | $V_{EN} = 0\text{V}$                        |             | 2     |             | $\mu\text{A}$    |
| <b>THERMAL SHUTDOWN</b> |  |   |             |       |             |                  |
| $T_{THERMSD}$           | Thermal Shutdown   |   |             | 165   |             | $^\circ\text{C}$ |
| $T_{THERMSDHYS}$        | Thermal Shutdown Hysteresis                                      |   |             | 10    |             | $^\circ\text{C}$ |

## 6.5 Typical Characteristics

Unless otherwise specified:  $V_{IN} = 5\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $L = 0.56\text{ }\mu\text{H}$  ( $1.8\text{-m}\Omega\text{ }R_{DCR}$ ),  $C_{SS} = 33\text{ nF}$ ,  $T_A = 25^\circ\text{C}$  for efficiency curves, loop gain plots and waveforms, and  $T_J = 25^\circ\text{C}$  for all others.



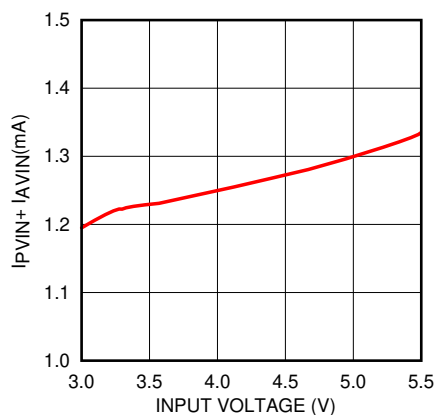
**Figure 6-1. Efficiency**



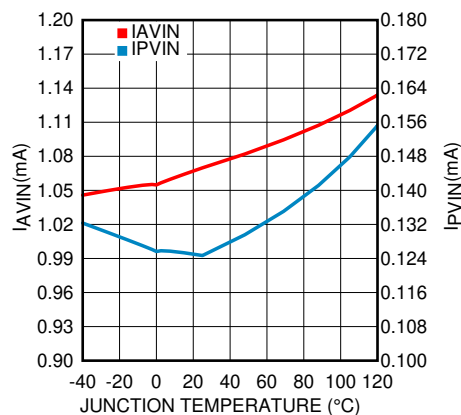
$V_{OUT} = 3.3\text{ V}$

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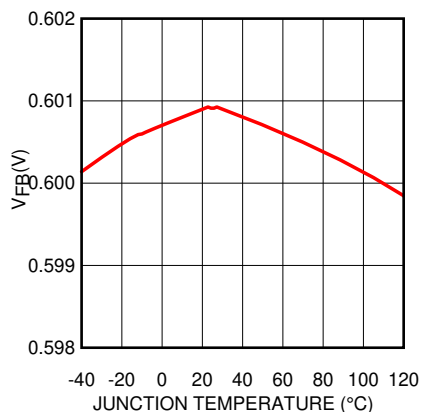
**Figure 6-2. Efficiency**



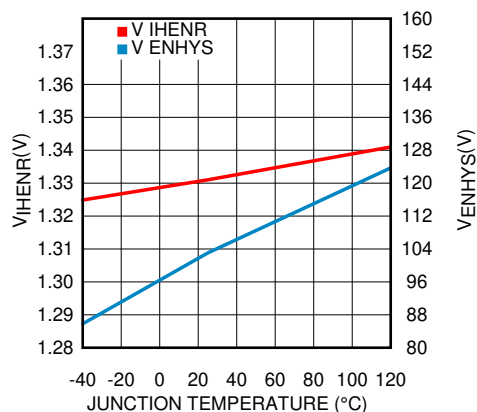
**Figure 6-3. Non-Switching  $I_{QTOTAL}$  vs  $V_{IN}$**



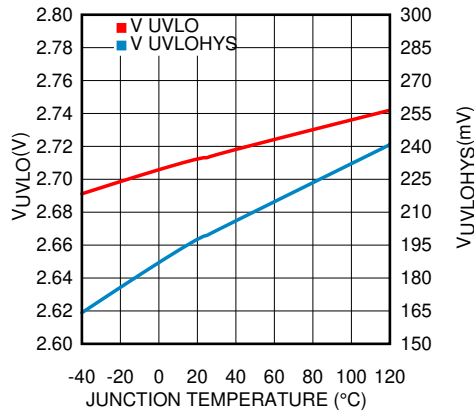
**Figure 6-4. Non-Switching  $I_{AVIN}$  and  $I_{PVIN}$  vs Temperature**



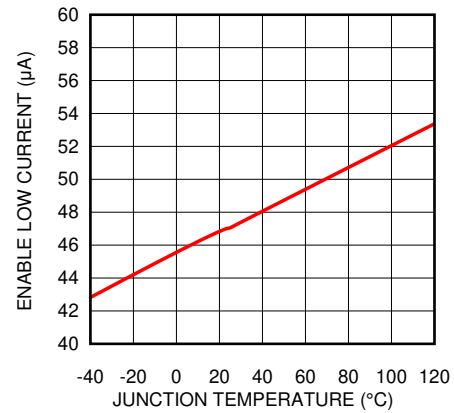
**Figure 6-5.  $V_{FB}$  vs Temperature**



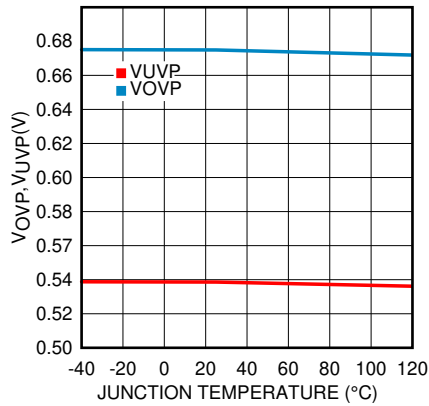
**Figure 6-6. Enable Threshold and Hysteresis vs Temperature**



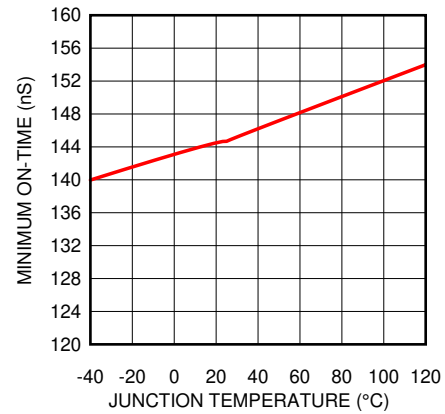
**Figure 6-7. UVLO Threshold and Hysteresis vs Temperature**



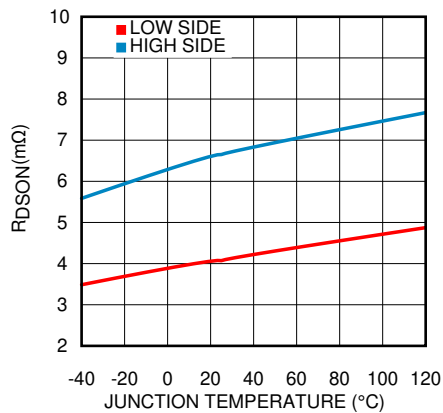
**Figure 6-8. Enable Low Current vs Temperature**



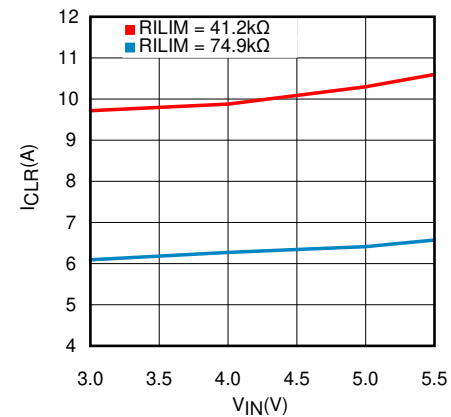
**Figure 6-9. OVP/UV Threshold vs Temperature**



**Figure 6-10. Minimum On-Time vs Temperature**



**Figure 6-11. FET Resistance vs Temperature**



**Figure 6-12. Peak Current Limit (ICLR) vs VIN**

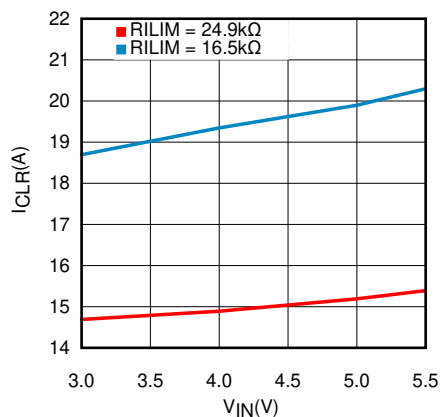
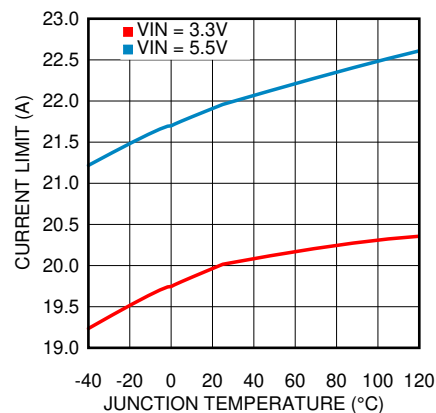
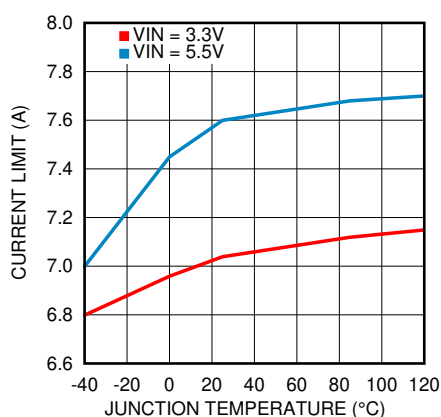
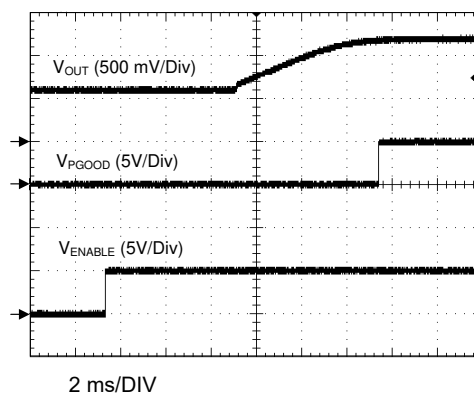
Figure 6-13. Peak Current Limit ( $I_{CLR}$ ) vs  $V_{IN}$  $R_{ILIM} = 10\text{ k}\Omega$ Figure 6-14. Peak Current Limit ( $I_{CLR}$ ) vs Temperature $R_{ILIM} = 61.9\text{ k}\Omega$ Figure 6-15. Peak Current Limit ( $I_{CLR}$ ) vs Temperature

Figure 6-16. Start-up With Prebiased Output

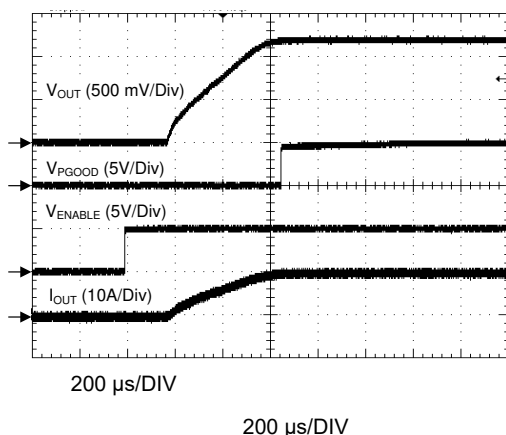


Figure 6-17. Start-up With SS/TRK Open Circuit

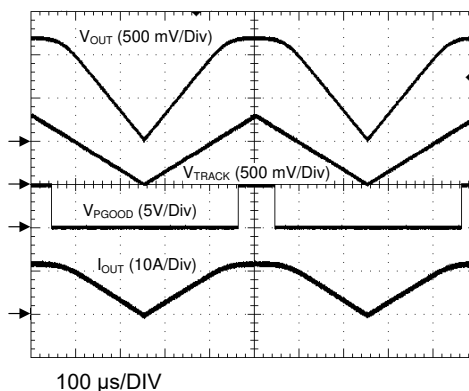
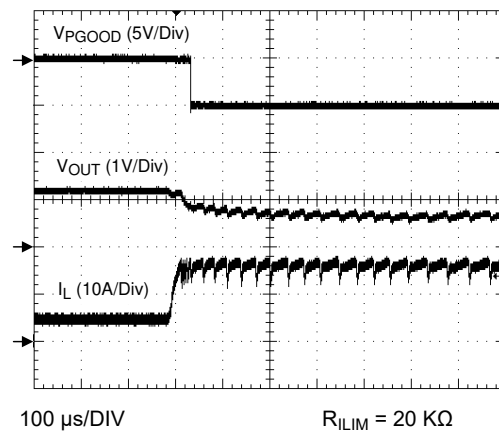


Figure 6-18. Start-up With Applied Track Signal





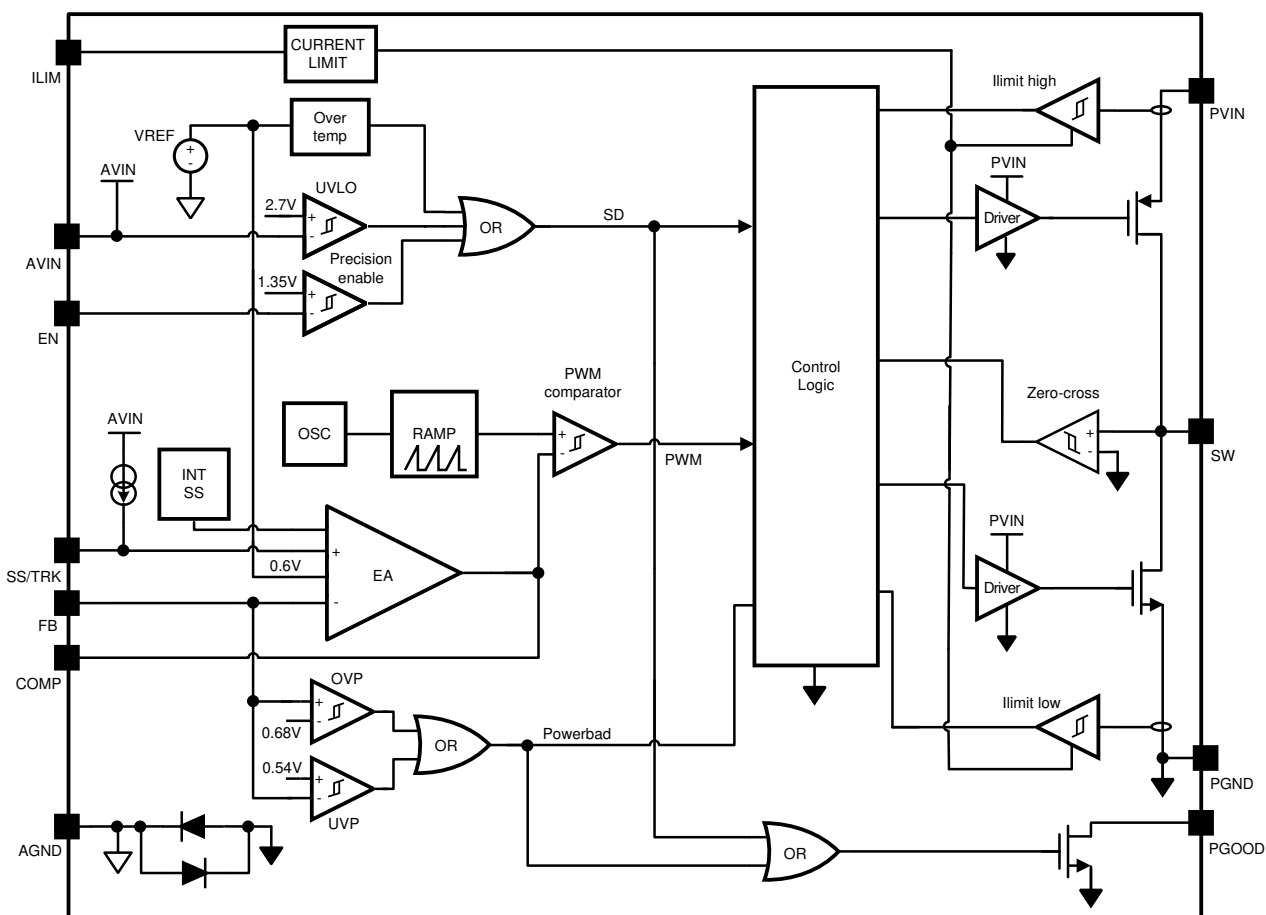
**Figure 6-19. Output Overcurrent Condition**

## 7 Detailed Description

### 7.1 Overview

The LM21215 switching regulator features all of the functions necessary to implement an efficient low voltage buck regulator using a minimum number of external components. This easy-to-use regulator features two integrated switches and is capable of supplying up to 15 A of continuous output current. The regulator utilizes voltage mode control with trailing edge modulation to optimize stability and transient response over the entire output voltage range. The precision internal voltage reference allows the output to be set as low as 0.6 V. Fault protection features include: current limiting, thermal shutdown, overvoltage protection, and shutdown capability. The device is available in the 20-pin HTSSOP package featuring an exposed pad to aid thermal dissipation. The LM21215 can be used in numerous applications to efficiently step-down from a 5-V or 3.3-V bus.

### 7.2 Functional Block Diagram



### 7.3 Feature Description

#### 7.3.1 Precision Enable

The enable (EN) pin allows the output of the device to be enabled or disabled with an external control signal. This pin is a precision analog input that enables the device when the voltage exceeds 1.35 V (typical). The EN pin has 110 mV of hysteresis and disables the output when the enable voltage falls below 1.24 V (typical). If the EN pin is not used, it can be left open, and will be pulled high by an internal 2- $\mu$ A current source. Since the enable pin has a precise turn-on threshold, it can be used along with an external resistor divider network from VIN to configure the device to turn on at a precise input voltage.

### 7.3.2 UVLO

The LM21215 has a built-in undervoltage lockout protection circuit that keeps the device from switching until the input voltage reaches 2.7 V (typical). The UVLO threshold has 200 mV of hysteresis that keeps the device from responding to power-on glitches during start-up. If desired, the turn-on point of the supply can be changed by using the precision enable pin and a resistor divider network connected to VIN as shown in [Figure 8-3](#) in the design guide.

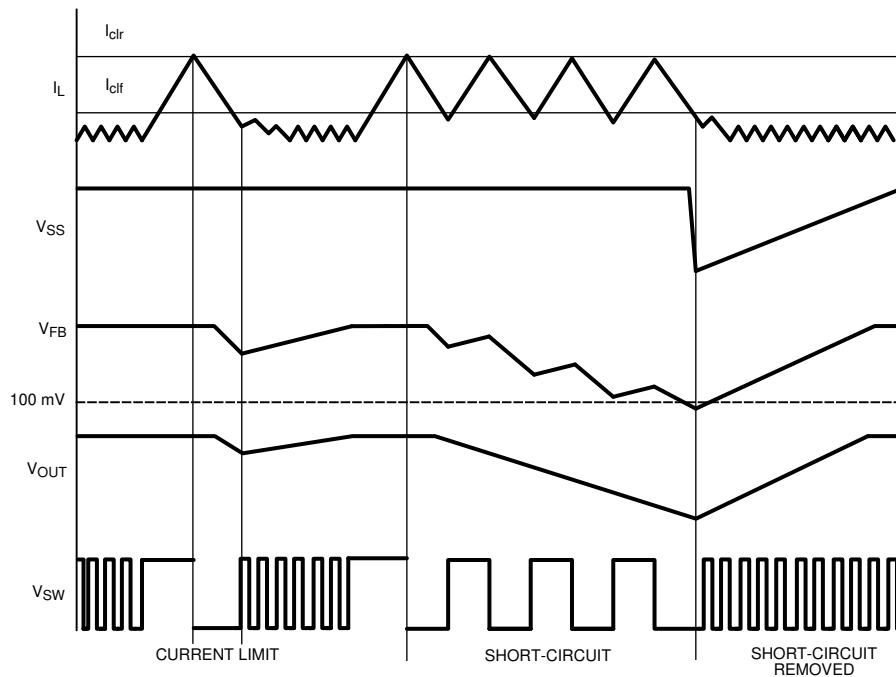
### 7.3.3 Current Limit

The LM21215 has programmable current limit protection to avoid dangerous current levels through the power FETs and inductor. A current limit condition is met when the current through the high side FET exceeds the rising current limit level ( $I_{CLR}$ ). The control circuitry will respond to this event by turning off the high-side FET and turning on the low-side FET. This forces a negative voltage on the inductor, thereby causing the inductor current to decrease. The high-side FET will not conduct again until the lower current limit level ( $I_{CLF}$ ) is sensed on the low-side FET. At this point, the device will resume normal switching.

A current limit condition will cause the internal soft-start voltage to ramp downward. After the internal soft-start ramps below the feedback (FB) pin voltage (nominally 0.6 V), FB will begin to ramp downward, as well. This voltage foldback will limit the power consumption in the device, thereby protecting the device from continuously supplying power to the load under a condition that does not fall within the device SOA. After the current limit condition is cleared, the internal soft-start voltage will ramp up again. [Figure 7-1](#) shows current limit behavior with  $V_{SS}$ ,  $V_{FB}$ ,  $V_{OUT}$ , and  $V_{SW}$ .

### 7.3.4 Short-Circuit Protection

In the unfortunate event that the output is shorted with a low impedance to ground, the LM21215 limits the current into the short by resetting the device. A short-circuit condition is sensed by a current-limit condition coinciding with a voltage on the FB pin that is lower than 100 mV. When this condition occurs, the device begins its reset sequence, turning off both power FETs and discharging the soft-start capacitor after  $t_{RESETSS}$  (nominally 110  $\mu$ s). The device will then attempt to restart. If the short-circuit condition still exists, it will reset again, and repeat until the short-circuit is cleared. The reset prevents excess current flowing through the FETs in a highly inefficient manner, potentially causing thermal damage to the device or the bus supply.



**Figure 7-1. Current Limit Conditions**

### 7.3.5 Thermal Protection

Internal thermal shutdown circuitry is provided to protect the integrated circuit in the event that the maximum junction temperature is exceeded. When activated, typically at 165°C, the LM21215 tri-states the power FETs and resets soft start. After the junction cools to approximately 155°C, the device starts up using the normal start-up routine. This feature is provided to prevent catastrophic failures from accidental device overheating. Note that thermal limit will not stop the die from operating above the specified maximum operating temperature, 125°C. The die should be kept under 125°C to ensure correct operation.

### 7.3.6 Light Load Operation

The LM21215 offers increased efficiency when operating at light loads. Whenever the load current is reduced to a point where the peak to peak inductor ripple current is greater than two times the load current, the device will enter the diode emulation mode, preventing significant negative inductor current. The point at which this occurs is the critical conduction boundary and can be calculated with [Equation 1](#):

$$I_{\text{BOUNDARY}} = \frac{(V_{\text{IN}} - V_{\text{OUT}}) \times D}{2 \times L \times f_{\text{SW}}} \quad (1)$$

It can be seen that in diode emulation mode, whenever the inductor current reaches zero, the SW node becomes high impedance. Ringing will occur on this pin as a result of the LC tank circuit formed by the inductor and the parasitic capacitance at the node. If this ringing is of concern, an additional RC snubber circuit can be added from the switch node to ground.

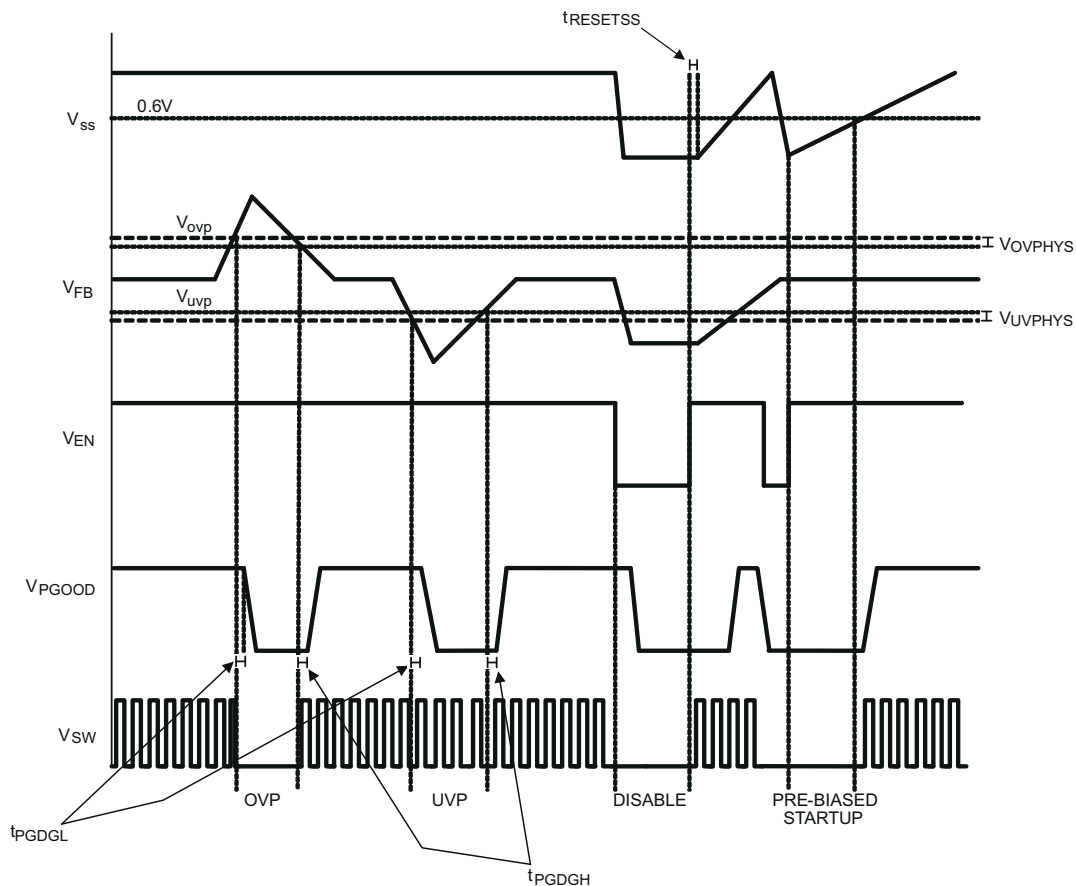
At very light loads, usually below 100 mA, several pulses can be skipped in between switching cycles, effectively reducing the switching frequency and further improving light-load efficiency.

### 7.3.7 Power Good Flag

The PGOOD pin provides the user with a way to monitor the status of the LM21215. In order to use the PGOOD pin, the application must provide a pullup resistor to a desired DC voltage (in other words,  $V_{\text{IN}}$ ). PGOOD will respond to a fault condition by pulling the PGOOD pin low with the open-drain output. PGOOD pulls low on the following conditions:

- $V_{\text{FB}}$  moves above or below the  $V_{\text{OVP}}$  or  $V_{\text{UVP}}$ , respectively.
- The enable pin (EN) is brought below the enable threshold.
- The device enters a prebiased output condition ( $V_{\text{FB}} > V_{\text{SS}}$ ).

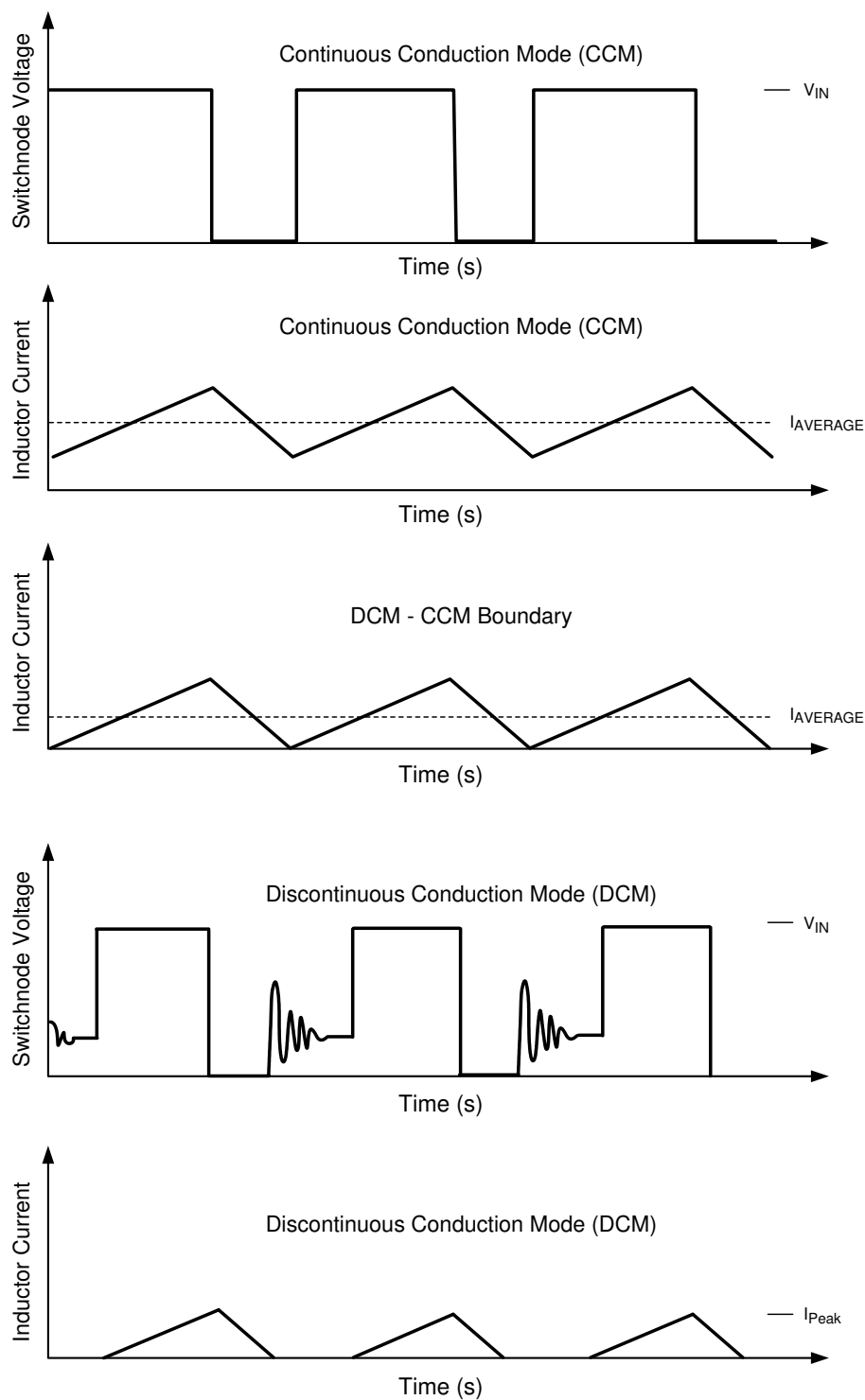
[Figure 7-2](#) shows the conditions that will cause PGOOD to fall.



**Figure 7-2. PGOOD Conditions**

## 7.4 Device Functional Modes

Several diagrams are shown in illustrating continuous conduction mode (CCM), discontinuous conduction mode (DCM), and the boundary condition.



**Figure 7-3. Modes Of Operation for LM21215**

## 8 Application and Implementation

### Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

### 8.1 Application Information

The LM21212-2 switching regulator features all of the functions necessary to implement an efficient low voltage buck regulator using a minimum number of external components. This easy-to-use regulator features two integrated switches and is capable of supplying up to 12 A of continuous output current. The regulator utilizes voltage mode control with trailing edge modulation to optimize stability and transient response over the entire output voltage range.

### 8.2 Typical Application

#### 8.2.1 Typical Application 1

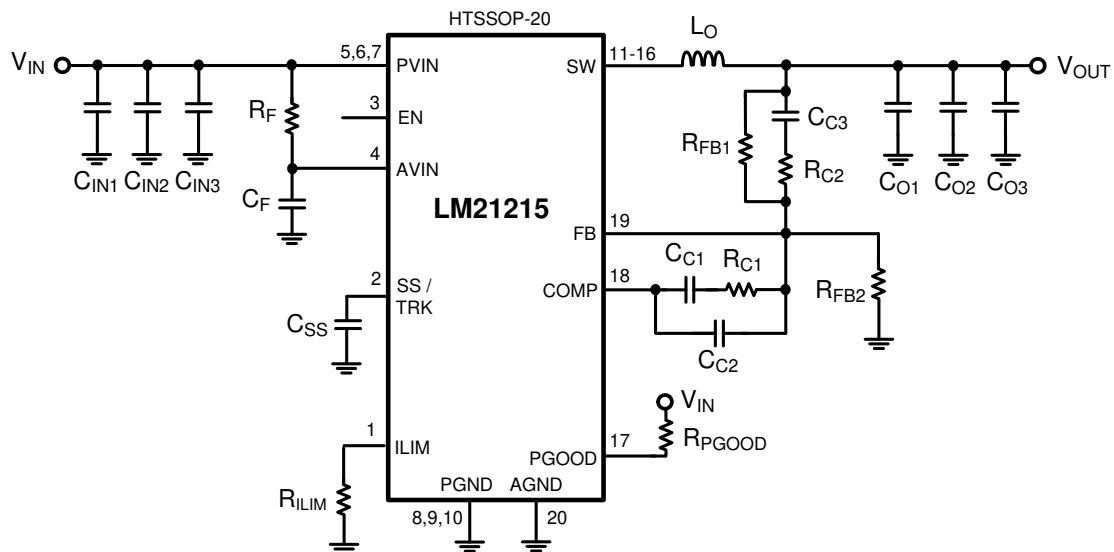


Figure 8-1. Typical Application Schematic 1

### 8.2.1.1 Design Requirements

**Table 8-1. Bill Of Materials ( $V_{IN} = 3.3\text{ V}$ – $5.5\text{ V}$ ,  $V_{OUT} = 1.2\text{ V}$ ,  $I_{OUT} = 15\text{ A}$ )**

| ID   | DESCRIPTION  | VENDOR      | PART NUMBER        | QUANTITY |
|--|--|-------------|--------------------|----------|
| $C_F$  | CAP, CERM, 1 $\mu\text{F}$ , 10 V, $\pm 10\%$ , X7R, 0603                          | MuRata      | GRM188R71A105KA61D | 1        |
| $C_{IN1}$ , $C_{IN2}$ ,<br>$C_{IN3}$ , $C_{O1}$ , $C_{O2}$ ,<br>$C_{O3}$ | CAP, CERM, 100 $\mu\text{F}$ , 6.3 V, $\pm 20\%$ , X5R, 1206                       | MuRata      | GRM31CR60J107ME39L | 6        |
| $C_{C1}$   | CAP, CERM, 1800 pF, 50 V, $\pm 5\%$ , C0G/NP0, 0603                                | TDK         | C1608C0G1H182J     | 1        |
| $C_{C2}$   | CAP, CERM, 68 pF, 50 V, $\pm 5\%$ , C0G/NP0, 0603                                  | TDK         | C1608C0G1H680J     | 1        |
| $C_{C3}$   | CAP, CERM, 820 pF, 50 V, $\pm 5\%$ , C0G/NP0, 0603                                 | TDK         | C1608C0G1H821J     | 1        |
| $C_{SS}$   | CAP, CERM, 0.033 $\mu\text{F}$ , 16 V, $\pm 10\%$ , X7R, 0603                      | MuRata      | GRM188R71C333KA01D | 1        |
| $L_O$  | Inductor, Shielded Drum Core, Powdered Iron, 560 nH, 27.5 A, 0.0018 $\Omega$ , SMD | Vishay-Dale | IHLP4040DZERR56M01 | 1        |
| $R_F$  | RES, 1.0 $\Omega$ , 5%, 0.1 W, 0603  | Vishay-Dale | CRCW06031R00JNEA   | 1        |
| $R_{C1}$   | RES, 9.31 k $\Omega$ , 1%, 0.1 W, 0603   | Vishay-Dale | CRCW06039K31FKEA   | 1        |
| $R_{C2}$   | RES, 165 $\Omega$ , 1%, 0.1 W, 0603  | Vishay-Dale | CRCW0603165RFKEA   | 1        |
| $R_{FB1}$ , $R_{FB2}$ ,<br>$R_{PGOOD}$                                   | RES, 10 k $\Omega$ , 1%, 0.1 W, 0603   | Vishay-Dale | CRCW060310K0FKEA   | 3        |
| $R_{ILIM}$   | RES, 7.15 k $\Omega$ , 1%, 0.1 W, 0603   | Vishay-Dale | CRCW06037K15FKEA   | 1        |

### 8.2.1.2 Detailed Design Procedure

#### 8.2.1.2.1 Custom Design With WEBENCH® Tools

[Click here](#) to create a custom design using the LM21215 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage ( $V_{IN}$ ), output voltage ( $V_{OUT}$ ), and output current ( $I_{OUT}$ ) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

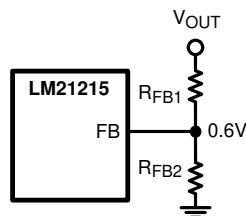
In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at [www.ti.com/WEBENCH](http://www.ti.com/WEBENCH).

#### 8.2.1.2.2 Output Voltage

The first step in designing the LM21215 application is setting the output voltage. This is done by using a voltage divider between  $V_{OUT}$  and AGND, with the middle node connected to  $V_{FB}$ . When operating under steady-state conditions, the LM21215 forces  $V_{OUT}$  so that  $V_{FB}$  is driven to 0.6 V.



**Figure 8-2. Setting  $V_{OUT}$**

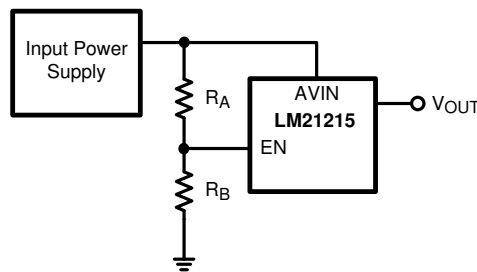


A good starting point for the lower feedback resistor,  $R_{FB2}$ , is 10 k $\Omega$ .  $R_{FB1}$  can then be calculated with Equation 2:

$$V_{OUT} = \frac{R_{FB1} + R_{FB2}}{R_{FB2}} 0.6V \quad (2)$$

### 8.2.1.2.3 Precision Enable

The enable (EN) pin of the LM21215 allows the output to be toggled on and off. This pin is a precision analog input. When the voltage exceeds 1.35 V, the controller will try to regulate the output voltage as long as the input voltage has exceeded the UVLO voltage of 2.7 V. There is an internal current source connected to EN so if enable is not used, the device will turn on automatically. If EN is not toggled directly, the device can be pre-programmed to turn on at a certain input voltage higher than the UVLO voltage. This can be done with an external resistor divider from AVIN to EN and EN to AGND as shown in Figure 8-3.



**Figure 8-3. Enable Start-Up Through  $V_{IN}$**

The resistor values of  $R_A$  and  $R_B$  can be relatively sized to allow EN to reach the enable threshold voltage depending on the input supply voltage. With the enable current source accounted for, the equation solving for  $R_A$  is the following:

$$R_A = \frac{R_B(V_{PVIN} - 1.35V)}{1.35V - I_{EN}R_B} \quad (3)$$

where

- $R_A$  is the resistor from  $V_{IN}$  to enable.
- $R_B$  is the resistor from enable to ground.
- $I_{EN}$  is the internal enable pullup current (2  $\mu$ A).
- 1.35 V is the fixed precision enable threshold voltage.

Typical values for  $R_B$  range from 10 k $\Omega$  to 100 k $\Omega$ .

### 8.2.1.2.4 Soft Start

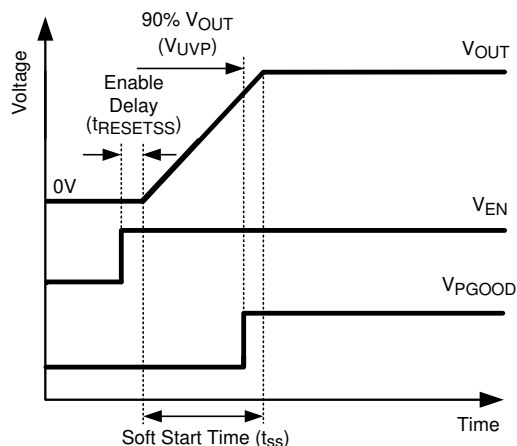
When EN has exceeded 1.35 V, and both PVIN and AVIN have exceeded the UVLO threshold, the LM21215 begins charging the output linearly to the voltage level dictated by the feedback resistor network. The LM21215 employs a user-adjustable soft-start circuit to lengthen the charging time of the output set by a capacitor from the soft-start pin to ground. After enable exceeds 1.35 V, an internal 2- $\mu$ A current source begins to charge the soft-start capacitor. This allows the user to limit inrush currents due to a high output capacitance and not cause an overcurrent condition. Adding a soft-start capacitor can also reduce the stress on the input rail. Larger capacitor values will result in longer start-up times. Use Equation 4 to approximate the size of the soft-start capacitor:

$$\frac{t_{SS} \times I_{SS}}{0.6V} = C_{SS} \quad (4)$$

where

- $I_{SS}$  is nominally  $2\ \mu\text{A}$ .
- $t_{SS}$  is the desired start-up time.

If  $V_{IN}$  is higher than the UVLO level and enable is toggled high the soft start sequence begins. There is a small delay between enable transitioning high and the beginning of the soft start sequence. This delay allows the LM21215 to initialize its internal circuitry. Once the output has charged to 90% of the nominal output voltage the power-good flag transitions high. This behavior is illustrated in Figure 8-4.

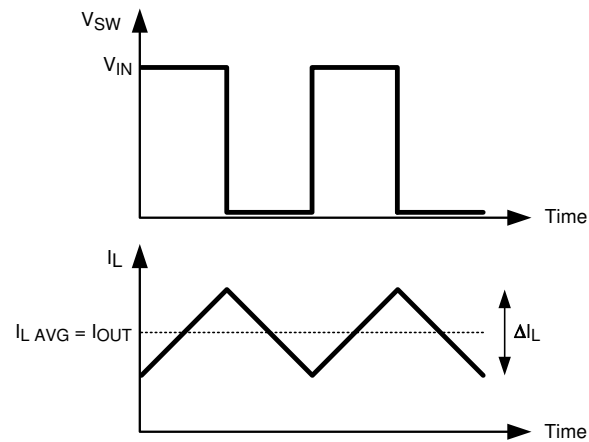


**Figure 8-4. Soft-Start Timing**

As shown above, the size of the capacitor is influenced by the nominal feedback voltage level 0.6 V, the soft-start charging current,  $I_{SS}$  ( $2\ \mu\text{A}$ ), and the desired soft-start time. If no soft-start capacitor is used, then the LM21215 defaults to a minimum start-up time of  $500\ \mu\text{s}$ . The LM21215 does not start up faster than  $500\ \mu\text{s}$ . When enable is cycled or the device enters UVLO, the charge developed on the soft-start capacitor is discharged to reset the start-up process. This also happens when the device enters short circuit mode from an overcurrent event.

#### 8.2.1.2.5 Inductor Selection

The inductor (L) used in the application influences the ripple current and the efficiency of the system. The first selection criteria is to define a ripple current,  $\Delta I_L$ . In a buck converter, it is typically selected to run between 20% to 30% of the maximum output current. Figure 8-5 shows the ripple current in a standard buck converter operating in continuous conduction mode. Larger ripple current results in a smaller inductance value, which will lead to a lower series resistance in the inductor and improved efficiency. However, larger ripple current will also cause the device to operate in discontinuous conduction mode at a higher average output current.



**Figure 8-5. Switch And Inductor Current Waveforms**

Once the ripple current has been determined, the appropriate inductor size can be calculated using [Equation 5](#):

$$L = \frac{(V_{IN} - V_{OUT}) \cdot D}{\Delta I_L \cdot f_{SW}} \quad (5)$$

#### 8.2.1.2.6 Output Capacitor Selection

The output capacitor,  $C_{OUT}$ , filters the inductor ripple current and provides a source of charge for transient load conditions. A wide range of output capacitors can be used with the LM21215 that provide various advantages. The best performance is typically obtained using ceramic, SP, or OSCON type chemistries. Typical trade-offs are that the ceramic capacitor provides extremely low ESR to reduce the output ripple voltage and noise spikes, while the SP and OSCON capacitors provide a large bulk capacitance in a small volume for transient loading conditions.

When selecting the value for the output capacitor, the two performance characteristics to consider are the output voltage ripple and transient response. The output voltage ripple can be approximated by using [Equation 6](#):

$$\Delta V_{OUT} \approx \Delta I_L \times \left[ R_{ESR} + \frac{1}{8 \times f_{SW} \times C_{OUT}} \right] \quad (6)$$

where

- $\Delta V_{OUT}$  (V) is the amount of peak-to-peak voltage ripple at the power supply output.
- $R_{ESR}$  ( $\Omega$ ) is the series resistance of the output capacitor.
- $f_{SW}$  (Hz) is the switching frequency.
- $C_{OUT}$  (F) is the output capacitance used in the design.

The amount of output ripple that can be tolerated is application specific, however, a general recommendation is to keep the output ripple less than 1% of the rated output voltage. Keep in mind ceramic capacitors are sometimes preferred because they have very low ESR, however, depending on package and voltage rating of the capacitor, the value of the capacitance can drop significantly with applied voltage. The output capacitor selection will also affect the output voltage droop during a load transient. The peak droop on the output voltage during a load transient is dependent on many factors, however, an approximation of the transient droop ignoring loop bandwidth can be obtained using [Equation 7](#):

$$V_{DROOP} = \Delta I_{OUTSTEP} \times R_{ESR} + \frac{L \times \Delta I_{OUTSTEP}^2}{C_{OUT} \times (V_{IN} - V_{OUT})} \quad (7)$$

where

- $C_{OUT}$  (F) is the minimum required output capacitance.
- $L$  (H) is the value of the inductor.
- $V_{DROOP}$  (V) is the output voltage drop ignoring loop bandwidth considerations.
- $\Delta I_{OUTSTEP}$  (A) is the load step change.
- $R_{ESR}$  ( $\Omega$ ) is the output capacitor ESR.
- $V_{IN}$  (V) is the input voltage.
- $V_{OUT}$  (V) is the set regulator output voltage.

Examine both the tolerance and voltage coefficient of the capacitor when designing for a specific output ripple or transient droop target.

#### 8.2.1.2.7 Input Capacitor Selection

Quality input capacitors are necessary to limit the ripple voltage at the VIN pin while supplying most of the switch current during the on time. Additionally, they help minimize input voltage droop in an output current transient condition. In general, it is recommended to use a ceramic capacitor for the input as it provides both a low impedance and small footprint. Use of a high grade dielectric for the ceramic capacitor, such as X5R or X7R, will

provide improved overtemperature performance and also minimize the DC voltage derating that occurs with Y5V capacitors. The input capacitors  $C_{IN1}$  and  $C_{IN2}$  must be placed as close as possible to the PVIN and PGND pins.

Select non-ceramic input capacitors for RMS current rating and minimum ripple voltage. A good approximation for the required ripple current rating is given by the relationship:

$$I_{IN-RMS} = I_{OUT} \sqrt{D(1-D)} \quad (8)$$

As indicated by the RMS ripple current equation, the highest requirement for RMS current rating occurs at 50% duty cycle. For this case, the RMS ripple current rating of the input capacitor should be greater than half the output current. For best performance, low-ESR ceramic capacitors should be placed in parallel with higher capacitance capacitors to provide the best input filtering for the device.

When operating at low input voltages (3.3 V or lower), additional capacitance can be necessary to protect from triggering an undervoltage condition on an output current transient. This will depend on the impedance between the input voltage supply and the LM21215, as well as the magnitude and slew rate of the output transient.

The AVIN pin requires a 1- $\mu$ F ceramic capacitor to AGND and a 1- $\Omega$  resistor to PVIN. This RC network filters inherent noise on PVIN from the sensitive analog circuitry connected to AVIN.

#### 8.2.1.2.8 Programmable Current Limit

A resistor from the ILIM pin to GND sets the internal current limit on the LM21215. Program the current limit so that the peak inductor current ( $I_L$ ) does not trigger the current limit in normal operation. This requires setting the resistor from the ILIM pin to GND ( $R_{ILIM}$ ) to the appropriate value to allow the maximum ripple current,  $\Delta I_{LMAX}$  plus the DC output current through the high-side FET during normal operation. The maximum ripple current can be described as:

$$\begin{aligned} &\text{For } D > 0.5 \\ \Delta I_{LMAX} &= \frac{(V_{INMAX} - V_{OUTMIN}) \cdot V_{OUTMIN}}{L_{MIN} \cdot f_{SWMIN} \cdot V_{INMAX}} \\ &\text{For } D < 0.5 \\ \Delta I_{LMAX} &= \frac{(V_{INMIN} - V_{OUTMAX}) \cdot V_{OUTMAX}}{L_{MIN} \cdot f_{SWMIN} \cdot V_{INMIN}} \end{aligned} \quad (9)$$

where

- $V_{INMAX}$ ,  $V_{INMIN}$ ,  $V_{OUTMAX}$ ,  $V_{OUTMIN}$ ,  $L_{MIN}$ , and  $F_{SWMIN}$  are the respective maximum and minimum conditions of the system as defined by the component tolerance and device variation.

From this, the maximum allowable current through the high-side FET ( $I_{HSMAX}$ ) of device can be described as:

$$I_{HSMAX} = \frac{\Delta I_{LMAX}}{2} + I_{DCMAX} \quad (10)$$

where

- $I_{OUTMAX}$  is the maximum defined DC output current, up to 15 A.

Once the  $I_{HSMAX}$  value has been determined, a nominal value of the  $R_{ILIM}$  resistor can be calculated as follows:

$$R_{ILIM} (k\Omega) = \frac{582.4}{I_{HSMAX}} - 14.2 \quad (11)$$

where

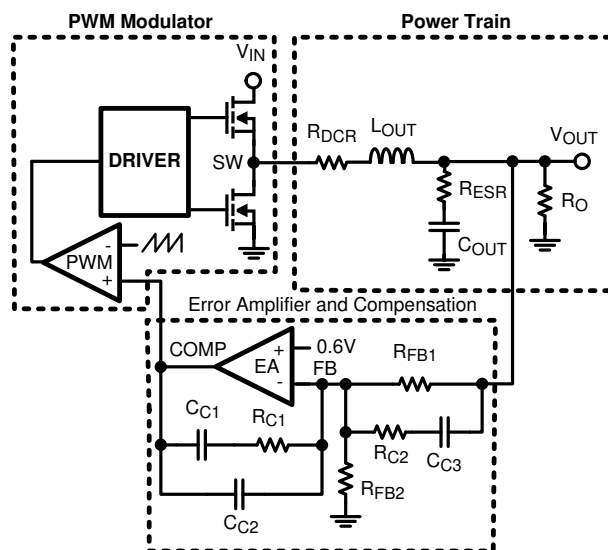
- $R_{ILIM}$  value is the nominal resistance necessary for the given  $I_{HSMAX}$  value.

A conservative design should also take into account the device variation over  $V_{IN}$  and temperature, as seen in the [Electrical Characteristics](#) for the  $I_{CLR}$  parameter and the typical performance characteristics. These variations can cause the  $I_{HSMAX}$  value to increase, depending on the range of the input voltage and junction temperature.

#### 8.2.1.2.9 Control Loop Compensation

The LM21215 incorporates a high bandwidth amplifier between the FB and COMP pins to allow the user to design a compensation network that matches the application. This section will walk through the various steps in obtaining the open loop transfer function.

There are three main blocks of a voltage mode buck switcher that the power supply designer must consider when designing the control system: the power train, modulator, and the compensated error amplifier. A closed loop diagram is shown in [Figure 8-6](#).



**Figure 8-6. Loop Diagram**

The power train consists of the output inductor ( $L$ ) with DCR (DC resistance  $R_{DCR}$ ), output capacitor ( $C_0$ ) with ESR (effective series resistance  $R_{ESR}$ ), and load resistance ( $R_o$ ). The error amplifier (EA) constantly forces FB to 0.6 V. The passive compensation components around the error amplifier help maintain system stability. The modulator creates the duty cycle by comparing the error amplifier signal with an internally generated ramp set at the switching frequency.

There are three transfer functions that must be taken into consideration when obtaining the total open loop transfer function: COMP to SW (modulator), SW to  $V_{OUT}$  (power train), and  $V_{OUT}$  to COMP (error amplifier). The COMP to SW transfer function is simply the gain of the PWM modulator.

$$G_{PWM} = \frac{V_{in}}{\Delta V_{ramp}} \quad (12)$$

where

- $\Delta V_{RAMP}$  is the oscillator peak-to-peak ramp voltage (nominally 0.8 V).

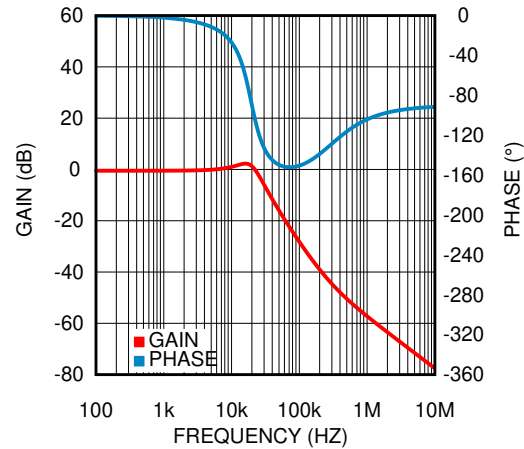
The SW to COMP transfer function includes the output inductor, output capacitor, and output load resistance. The inductor and capacitor create two complex poles at a frequency described by:

$$f_{LC} = \frac{1}{2\pi} \sqrt{\frac{R_o + R_{DCR}}{L_{OUT}C_{OUT}(R_o + R_{ESR})}} \quad (13)$$

In addition to two complex poles, a left half plane zero is created by the output capacitor ESR located at a frequency described by:

$$f_{\text{esr}} = \frac{1}{2\pi C_0 R_{\text{esr}}} \quad (14)$$

A Bode plot showing the power train response can be seen in [Figure 8-7](#).

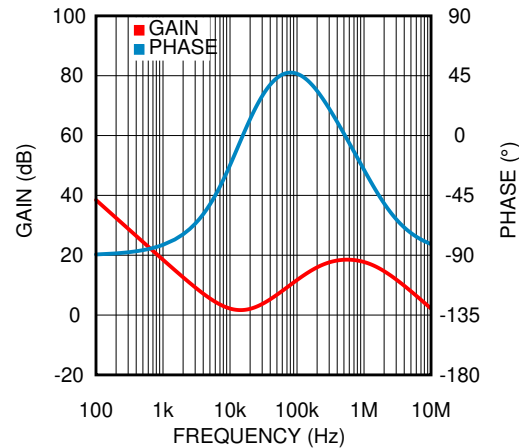


**Figure 8-7. Power Train Bode Plot**

The complex poles created by the output inductor and capacitor cause a 180° phase shift at the resonant frequency as seen in [Figure 8-7](#). The phase is boosted back up to -90° due to the output capacitor ESR zero. The 180° phase shift must be compensated out and phase boosted through the error amplifier to stabilize the closed loop response. The compensation network shown around the error amplifier in [Figure 8-6](#) creates two poles, two zeros, and a pole at the origin. Placing these poles and zeros at the correct frequencies stabilizes the closed loop response. The Compensated Error Amplifier transfer function is:

$$G_{\text{EA}} = K_m \frac{\left(\frac{s}{2\pi f_{z1}} + 1\right)\left(\frac{s}{2\pi f_{z2}} + 1\right)}{s\left(\frac{s}{2\pi f_{p1}} + 1\right)\left(\frac{s}{2\pi f_{p2}} + 1\right)} \quad (15)$$

The pole located at the origin gives high open loop gain at DC, translating into improved load regulation accuracy. This pole occurs at a very low frequency due to the limited gain of the error amplifier, however, it can be approximated at DC for the purposes of compensation. The other two poles and two zeros can be located accordingly to stabilize the voltage mode loop depending on the power stage complex poles and Q. [Figure 8-8](#) is an illustration of what the Error Amplifier Compensation transfer function will look like.



**Figure 8-8. Type 3 Compensation Network Bode Plot**

As seen in [Figure 8-8](#), the two zeros ( $f_{LC}/2$ ,  $f_{LC}$ ) in the compensation network give a phase boost. This will cancel out the effects of the phase loss from the output filter. The compensation network also adds two poles to the system. One pole should be located at the zero caused by the output capacitor ESR ( $f_{ESR}$ ), and the other pole must be at half the switching frequency ( $f_{SW}/2$ ) to roll off the high frequency response. The dependency of the pole and zero locations on the compensation components is described in [Equation 16](#).

$$\begin{aligned}
 f_{Z1} &= \frac{f_{LC}}{2} = \frac{1}{2\pi R_{C1} C_{C1}} \\
 f_{Z2} &= f_{LC} = \frac{1}{2\pi (R_{C1} + R_{FB1}) C_{C3}} \\
 f_{P1} &= f_{ESR} = \frac{1}{2\pi R_{C2} C_{C3}} \\
 f_{P2} &= \frac{f_{SW}}{2} = \frac{C_{C1} + C_{C2}}{2\pi R_{C1} C_{C1} C_{C2}}
 \end{aligned}
 \tag{16}$$

An example of the step-by-step procedure to generate compensation component values using the typical application setup, is given. The parameters needed for the compensation values are given in [Table 8-2](#).

**Table 8-2. Required Parameters for Compensation Values**

| PARAMETER         | VALUE          |
|-------------------|----------------|
| $V_{IN}$          | 5 V            |
| $V_{OUT}$         | 1.2 V          |
| $I_{OUT}$         | 15 A           |
| $f_{CROSSOVER}$   | 100 kHz        |
| $L$               | 0.56 $\mu$ H   |
| $R_{DCR}$         | 1.8 m $\Omega$ |
| $C_O$             | 150 $\mu$ F    |
| $R_{ESR}$         | 1.0 m $\Omega$ |
| $\Delta V_{RAMP}$ | 0.8 V          |
| $f_{SW}$          | 500 kHz        |

where  $\Delta V_{RAMP}$  is the oscillator peak-to-peak ramp voltage (nominally 0.8 V), and  $f_{CROSSOVER}$  is the frequency at which the open-loop gain is a magnitude of 1. It is recommended that the  $f_{CROSSOVER}$  not exceed one-fifth of the switching frequency. The output capacitance,  $C_O$ , depends on capacitor chemistry and bias voltage. For



multi-layer ceramic capacitors (MLCC), the total capacitance will degrade as the DC bias voltage is increased. Measuring the actual capacitance value for the output capacitors at the output voltage is recommended to accurately calculate the compensation network. The example given here is the total output capacitance using the three MLCC output capacitors biased at 1.2 V, as seen in [Figure 8-1](#). Note that it is more conservative, from a stability standpoint, to err on the side of a smaller output capacitance value in the compensation calculations rather than a larger, as this will result in a lower bandwidth but increased phase margin.

First, the value of  $R_{FB1}$  should be chosen. A typical value is 10 k $\Omega$ . From this, the value of  $R_{C1}$  can be calculated to set the mid-band gain so that the desired crossover frequency is achieved:

$$\begin{aligned} R_{C1} &= \frac{f_{\text{crossover}}}{f_{LC}} \cdot \frac{\Delta V_{\text{RAMP}}}{V_{IN}} \cdot R_{FB1} \\ &= \frac{100 \text{ kHz}}{17.4 \text{ kHz}} \cdot \frac{0.8 \text{ V}}{5.0 \text{ V}} \cdot 10 \text{ k}\Omega \\ &= 9.2 \text{ k}\Omega \end{aligned} \tag{17}$$

Next, the value of  $C_{C1}$  can be calculated by placing a zero at half of the LC double pole frequency ( $f_{LC}$ ):

$$\begin{aligned} C_{C1} &= \frac{1}{\pi f_{LC} R_{C1}} \\ &= 1.99 \text{ nF} \end{aligned} \tag{18}$$

Now the value of  $C_{C2}$  can be calculated to place a pole at half of the switching frequency ( $f_{SW}$ ):

$$\begin{aligned} C_{C2} &= \frac{C_{C1}}{\pi f_{SW} R_{C1} C_{C1} - 1} \\ &= 71 \text{ pF} \end{aligned} \tag{19}$$

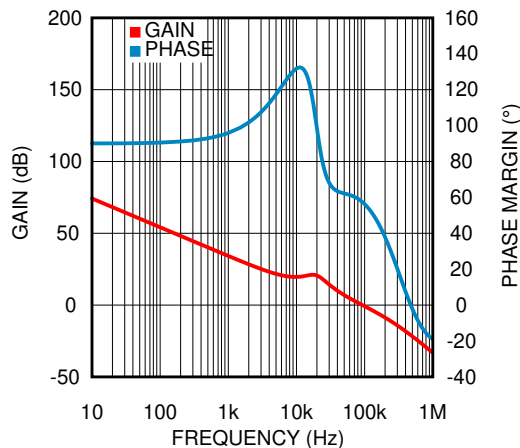
$R_{C2}$  can then be calculated to set the second zero at the LC double pole frequency:

$$\begin{aligned} R_{C2} &= \frac{R_{FB1} f_{LC}}{f_{ESR} - f_{LC}} \\ &= 166 \Omega \end{aligned} \tag{20}$$

Last,  $C_{C3}$  can be calculated to place a pole at the same frequency as the zero created by the output capacitor ESR:

$$\begin{aligned} C_{C3} &= \frac{1}{2\pi f_{ESR} R_{C2}} \\ &= 898 \text{ pF} \end{aligned} \tag{21}$$

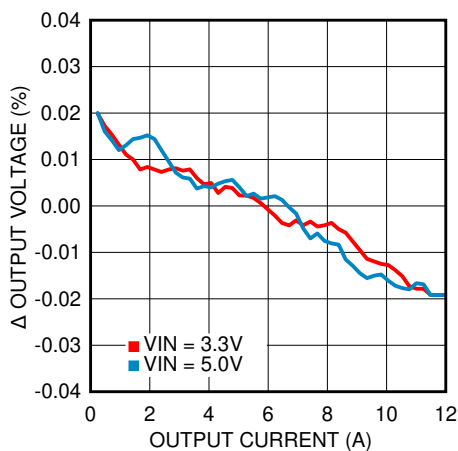
An illustration of the total loop response can be seen in [Figure 8-9](#).



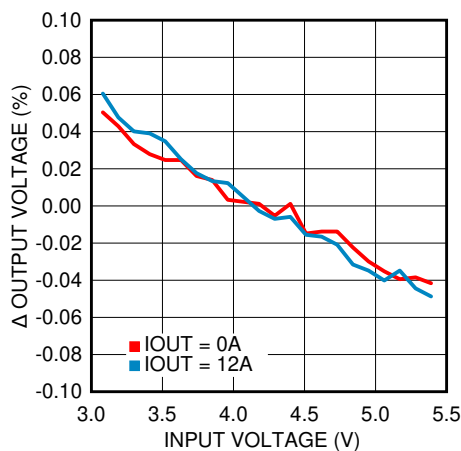
**Figure 8-9. Loop Response**

It is important to verify the stability by either observing the load transient response or by using a network analyzer. A phase margin between  $45^\circ$  and  $70^\circ$  is usually desired for voltage mode systems. Excessive phase margin can cause slow system response to load transients and low phase margin can cause an oscillatory load transient response. If the load step response peak deviation is larger than desired, increasing  $f_{\text{CROSSOVER}}$  and recalculating the compensation components can help, but usually at the expense of phase margin.

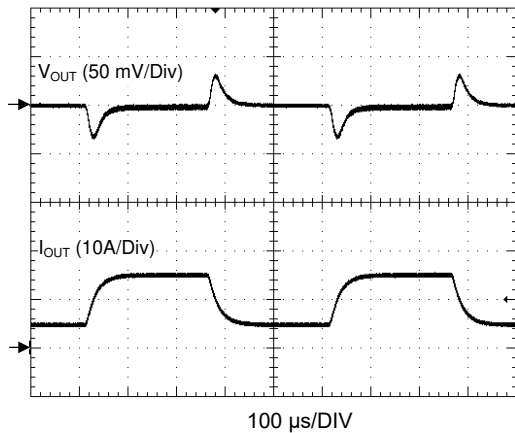
### 8.2.1.3 Application Curves



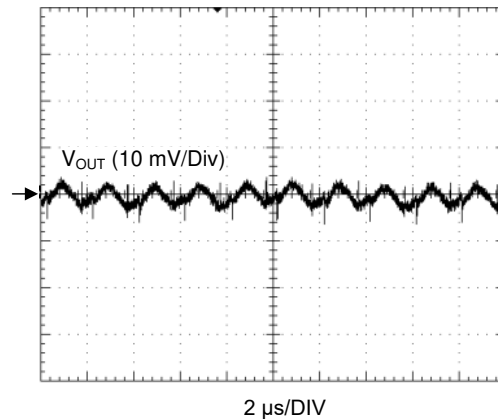
**Figure 8-10. Load Regulation**



**Figure 8-11. Line Regulation**



**Figure 8-12. Load Transient Response**



**Figure 8-13. Output Voltage Ripple ( $I_{OUT} = 15\text{ A}$ )**

## 8.2.2 Typical Application Schematic 2

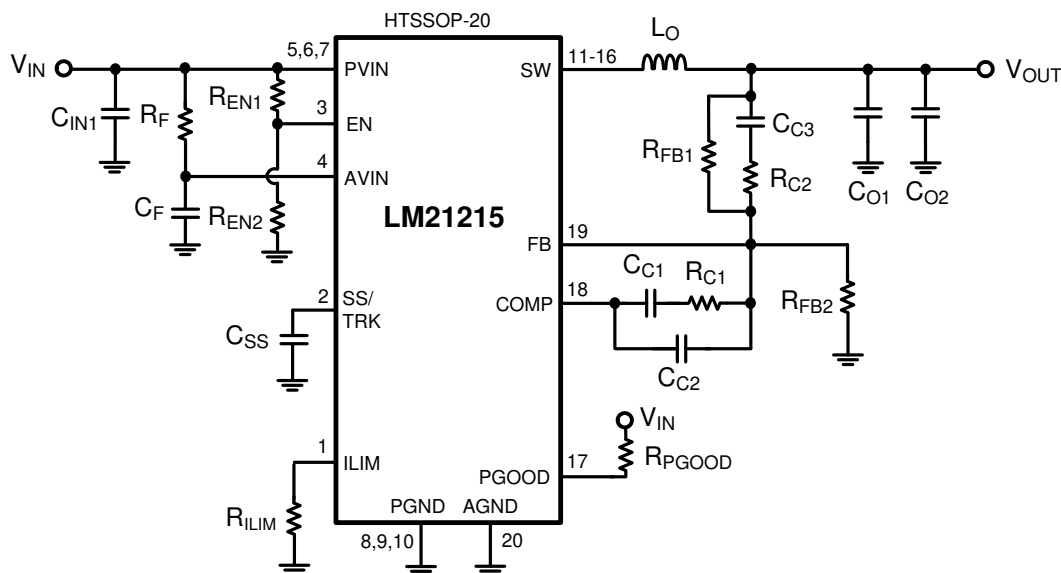


Figure 8-14. Typical Application Schematic 2

### 8.2.2.1 Design Requirements

Table 8-3. Bill Of Materials ( $V_{IN} = 4\text{ V} - 5.5\text{ V}$ ,  $V_{OUT} = 0.9\text{ V}$ ,  $I_{OUT} = 8\text{ A}$ )

| ID                                  | DESCRIPTION   | VENDOR      | PART NUMBER        | QUANTITY |
|-------------------------------------|---|-------------|--------------------|----------|
| $C_F$                               | CAP, CERM, 1 $\mu\text{F}$ , 10 V, $\pm 10\%$ , X7R, 0603         | MuRata      | GRM188R71A105KA61D | 1        |
| $C_{IN1}$ , $C_{O1}$ , $C_{O2}$     | CAP, CERM, 100 $\mu\text{F}$ , 6.3 V, $\pm 20\%$ , X5R, 1206      | MuRata      | GRM31CR60J107ME39L | 3        |
| $C_{C1}$                            | CAP, CERM, 1800 pF, 50 V, $\pm 5\%$ , C0G/NP0, 0603               | MuRata      | GRM1885C1H182JA01D | 1        |
| $C_{C2}$                            | CAP, CERM, 82 pF, 50 V, $\pm 5\%$ , C0G/NP0, 0603                 | TDK         | C1608C0G1H820J     | 1        |
| $C_{C3}$                            | CAP, CERM, 820 pF, 50 V, $\pm 5\%$ , C0G/NP0, 0603                | TDK         | C1608C0G1H821J     | 1        |
| $C_{SS}$                            | CAP, CERM, 0.033 $\mu\text{F}$ , 16 V, $\pm 10\%$ , X7R, 0603     | MuRata      | GRM188R71C333KA01D | 1        |
| $L_O$                               | Inductor, Shielded Drum Core, 680 nH, 22 A, 0.0014 $\Omega$ , SMD | Coilcraft   | XAL1060-681ME      | 1        |
| $R_F$                               | RES, 1.0 $\Omega$ , 5%, 0.1 W, 0603                               | Vishay-Dale | CRCW06031R00JNEA   | 1        |
| $R_{C1}$                            | RES, 8.25 k $\Omega$ , 1%, 0.1 W, 0603                            | Vishay-Dale | CRCW06038K25FKEA   | 1        |
| $R_{C2}$                            | RES, 124 $\Omega$ , 1%, 0.1 W, 0603                               | Vishay-Dale | CRCW0603124RFKEA   | 1        |
| $R_{EN1}$ , $R_{FB1}$ , $R_{PGOOD}$ | RES, 10 k $\Omega$ , 1%, 0.1 W, 0603                              | Vishay-Dale | CRCW060310K0FKEA   | 3        |
| $R_{EN2}$                           | RES, 19.6 k $\Omega$ , 1%, 0.1 W, 0603                            | Vishay-Dale | CRCW060319K6FKEA   | 1        |
| $R_{FB2}$                           | RES, 20.0 k $\Omega$ , 1%, 0.1 W, 0603                            | Vishay-Dale | CRCW060320K0FKEA   | 1        |
| $R_{ILIM}$                          | RES, 39.2 k $\Omega$ , 1%, 0.1 W, 0603                            | Vishay-Dale | CRCW060339K2FKEA   | 1        |

### 8.2.2.2 Detailed Design Procedure

See [Section 8.2.1.2](#)

## 9 Layout

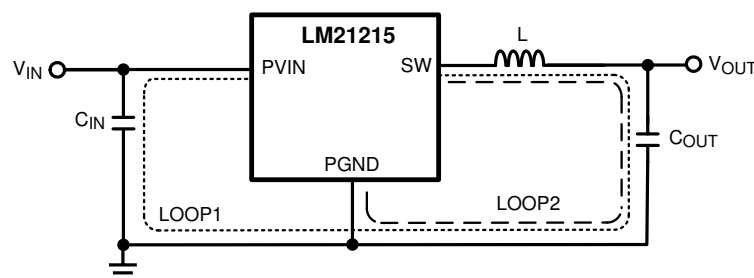
### 9.1 Layout Considerations

PC board layout is an important part of DC/DC converter design. Poor board layout can disrupt the performance of a DC/DC converter and surrounding circuitry by contributing to EMI, ground bounce, and resistive voltage loss in the traces. These can send erroneous signals to the DC/DC converter resulting in poor regulation or instability.

Good layout can be implemented by following a few simple design rules.

- Minimize area of switched current loops. In a buck regulator, there are two loops where currents are switched at high slew rates. The first loop starts from the input capacitor, to the regulator PVIN pin, to the regulator SW pin, to the inductor then out to the output capacitor and load. The second loop starts from the output capacitor ground, to the regulator GND pins, to the inductor and then out to the load (see [Figure 9-1](#)). To minimize both loop areas, place the input capacitor as close as possible to the VIN pin. Grounding for both the input and output capacitor must be close. Ideally, a ground plane should be placed on the top layer that connects the PGND pins, the exposed pad (EP) of the device, and the ground connections of the input and output capacitors in a small area near pin 10 and 11 of the device. The inductor should be placed as close as possible to the SW pin and output capacitor.
- Minimize the copper area of the switch node. Route the six SW pins on a single top plane to the pad of the inductor. Place the inductor should be placed to the switch pins of the device with a wide trace to minimize conductive losses. The inductor can be placed on the bottom side of the PCB relative to the LM21215, but care must be taken to not allow any coupling of the magnetic field of the inductor into the sensitive feedback or compensation traces.
- Have a solid ground plane between PGND, the EP, and the input and output capacitor ground connections. The ground connections for the AGND, compensation, feedback, and soft-start components should be physically isolated (located near pin 1 and 20) from the power ground plane but a separate ground connection is not necessary. If not properly handled, poor grounding can result in degraded load regulation or erratic switching behavior.
- Carefully route the connection from the VOUT signal to the compensation network. This node is high impedance and can be susceptible to noise coupling. The trace should be routed away from the SW pin and inductor to avoid contaminating the feedback signal with switch noise.
- Make input and output bus connections as wide as possible. This reduces any voltage drops on the input or output of the converter and can improve efficiency. Voltage accuracy at the load is important so make sure feedback voltage sense is made at the load. Doing so corrects for voltage drops at the load and provide the best output accuracy.
- Provide adequate device heat sinking. For most 15-A, designs a four layer board is recommended. Use as many vias as is possible to connect the EP to the power plane heatsink. The vias located underneath the EP wicks solder into them if they are not filled. Complete solder coverage of the EP to the board is required to achieve the  $\theta_{JA}$  values described in the previous section. Either an adequate amount of solder must be applied to the EP pad to fill the vias, or the vias must be filled during manufacturing. See [Section 9.2.1](#) to ensure enough copper heatsinking area is used to keep the junction temperature below 125°C.

### 9.2 Layout Example



**Figure 9-1. Schematic of LM21215 Highlighting Layout Sensitive Nodes**

## 9.2.1 Thermal Considerations

The thermal characteristics of the LM21215 are specified using the parameter  $\theta_{JA}$ , which relates the junction temperature to the ambient temperature. Although the value of  $\theta_{JA}$  is dependent on many variables, it still can be used to approximate the operating junction temperature of the device.

To obtain an estimate of the device junction temperature, one can use the following relationship:

$$T_J = P_D \cdot \theta_{JA} + T_A \quad (22)$$

and

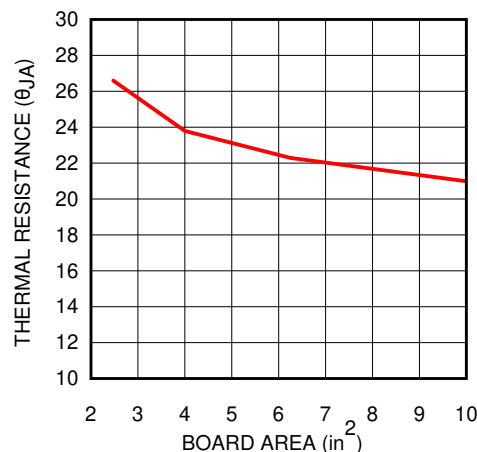
$$P_D = P_{IN} \cdot (1 - \text{Efficiency}) - I_{OUT}^2 \cdot R_{DCR} \quad (23)$$

where

- $T_J$  is the junction temperature in °C.
- $P_{IN}$  is the input power in Watts ( $P_{IN} = V_{IN} \times I_{IN}$ ).
- $\theta_{JA}$  is the junction to ambient thermal resistance for the LM21215.
- $T_A$  is the ambient temperature in °C.
- $I_{OUT}$  is the output load current in A.

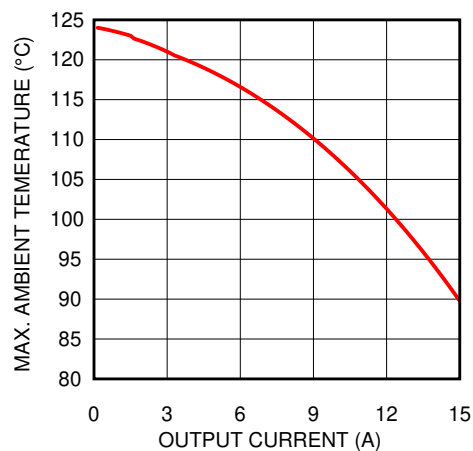
It is important to always keep the operating junction temperature ( $T_J$ ) below 125°C for reliable operation. If the junction temperature exceeds 165°C, the device cycles in and out of thermal shutdown. If thermal shutdown occurs, it is a sign of inadequate heat sinking or excessive power dissipation in the device.

Figure 9-2 provides a better approximation of the  $\theta_{JA}$  for a given PCB copper area. The PCB used in this test consisted of four layers: 1-oz. copper was used for the internal layers while the external layers were plated to 2-oz. copper weight. To provide an optimal thermal connection, a 3 × 5 array of 8-mil. vias under the thermal pad were used, and an additional twelve 8-mil. vias under the rest of the device were used to connect the four layers.



**Figure 9-2. Thermal Resistance vs PCB Area (4-Layer Board)**

Figure 9-3 shows a plot of the maximum ambient temperature vs output current for the typical application circuit shown in Figure 8-1, assuming a  $\theta_{JA}$  value of 24°C/W.



**Figure 9-3. Maximum Ambient Temperature vs Output Current (0 LFM)**

## 10 Device and Documentation Support

### 10.1 Device Support

#### 10.1.1 Third-Party Products Disclaimer

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#### 10.1.2 Development Support

##### 10.1.2.1 Custom Design With WEBENCH® Tools

[Click here](#) to create a custom design using the LM21215 device with the WEBENCH® Power Designer.

1. Start by entering the input voltage ( $V_{IN}$ ), output voltage ( $V_{OUT}$ ), and output current ( $I_{OUT}$ ) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at [www.ti.com/WEBENCH](http://www.ti.com/WEBENCH).

### 10.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 10.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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### 10.5 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 10.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.



## 11 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable part number           | Status<br>(1) | Material type<br>(2) | Package   Pins    | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|---------------------------------|---------------|----------------------|-------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">LM21215MH/NOPB</a>  | Active        | Production           | HTSSOP (PWP)   20 | 73   TUBE             | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | LM21215<br>MH       |
| LM21215MH/NOPB.A                | Active        | Production           | HTSSOP (PWP)   20 | 73   TUBE             | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | LM21215<br>MH       |
| <a href="#">LM21215MHE/NOPB</a> | Active        | Production           | HTSSOP (PWP)   20 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | LM21215<br>MH       |
| LM21215MHE/NOPB.A               | Active        | Production           | HTSSOP (PWP)   20 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | LM21215<br>MH       |
| LM21215MHE/NOPBG4.A             | Active        | Production           | HTSSOP (PWP)   20 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | LM21215<br>MH       |
| <a href="#">LM21215MHX/NOPB</a> | Active        | Production           | HTSSOP (PWP)   20 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | LM21215<br>MH       |
| LM21215MHX/NOPB.A               | Active        | Production           | HTSSOP (PWP)   20 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | LM21215<br>MH       |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM21215MHE/NOPB | HTSSOP       | PWP             | 20   | 250  | 178.0              | 16.4               | 6.95    | 7.0     | 1.4     | 8.0     | 16.0   | Q1            |
| LM21215MHX/NOPB | HTSSOP       | PWP             | 20   | 2500 | 330.0              | 16.4               | 6.95    | 7.0     | 1.4     | 8.0     | 16.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM21215MHE/NOPB | HTSSOP       | PWP             | 20   | 250  | 210.0       | 185.0      | 35.0        |
| LM21215MHX/NOPB | HTSSOP       | PWP             | 20   | 2500 | 367.0       | 367.0      | 35.0        |

## TUBE



\*All dimensions are nominal

| Device           | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|------------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| LM21215MH/NOPB   | PWP          | HTSSOP       | 20   | 73  | 495    | 8      | 2514.6 | 4.06   |
| LM21215MH/NOPB.A | PWP          | HTSSOP       | 20   | 73  | 495    | 8      | 2514.6 | 4.06   |

PWP (R-PDSO-G20)

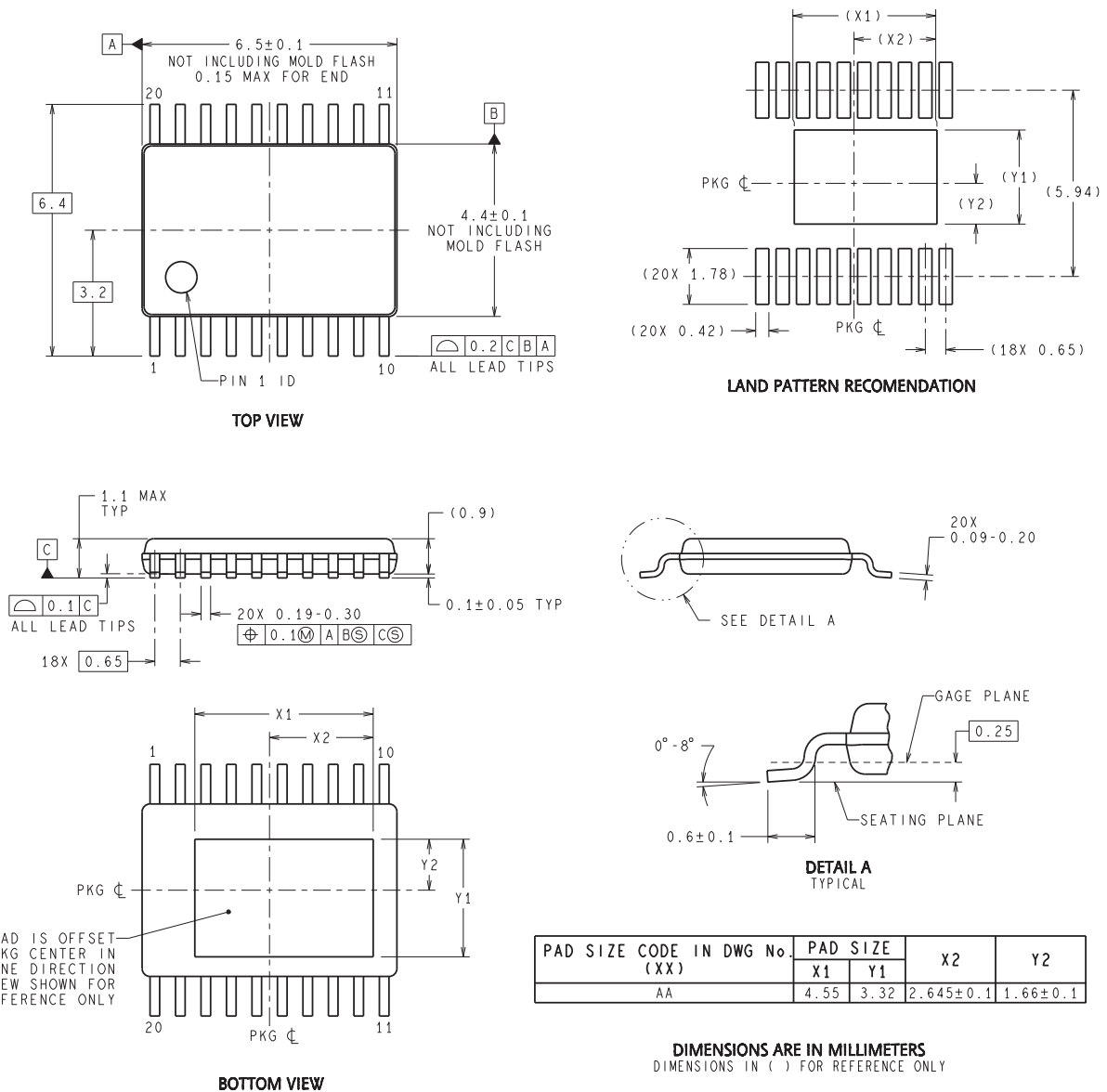
PowerPAD™ PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusions. Mold flash and protrusion shall not exceed 0.15 per side.
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
  - E. Falls within JEDEC MO-153

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PWP0020AA



MYB20XX (REV E)

4214875/A 02/2013

- NOTES: A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.  
B. This drawing is subject to change without notice.  
C. Reference JEDEC Registration MO-153, Variation ACT.



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